MEDICAL AND ENVIRONMENTAL APPLICATIONS OF ACTIVATED CHARCOAL: REVIEW ARTICLE

Ahed J Alkhatib
Jordan University Of Science And Technology, Jordan
Khalid Al Zailaey
Ministry Of Health, KSA

Abstract

This review article purposes to focus on the roles associated with activated charcoal (AC). While AC is mainly associated with treatment of poisoning substances, it has other important roles in the treatment of patients with chronic kidney disease which enhances the outcome of renal dialysis. We also indicated to the use of AC in providing protection for workers against vapors in working atmosphere through the use of charcoal cartridge. AC has potential roles in removal of heavy metals from environment particularly water. AC has therapeutic and environmental applications due to its large surface area.

Taken together, AC various applications which have to taken seriously to offer benefits other than being used for treating poisoning substances.

Keywords: Activated charcoal, poisoning substances, environment, charcoal cartridge

Introduction

Activated charcoal is a universal antidote for the majority of poisons (Maklad et al., 2012). The use of activated charcoal to treat poisonings has been known as early as 1830 by the french chemist bertrand. Activated charcoal is usually produced through the process of pyrolysis of materials that contain carbon and it is activated by oxidation with steam at a high temperature. Activated charcoal has a surface area about 1000m2/g and has the ability to adsorb many drugs (Harish et al., 2011).

Activated charcoal has other positive effects including lowering the resorption of agents that are involved in enterohepatic or enterogastric cycling as well as effecs on gastrointestinal dialysis (Neuvonen and Olkkola, 1988).

Activated charcoal is considered as the first-line agent in treating poisoning specially after passing several hours since ingestion. It is rarely to have complications associated with the use of activated charcoal, but in case they are encountered, they include aspiration of activated charcoal and gastric contents, in addition to intestinal obstruction, particularly when repeated doses of activated charcoal are given (Rowden et al., 1990; Buckley et al., 1993). It has been recommended to use multiple-dose activated charcoal for the clearance of certain drugs including carbamazepine, digitoxin, glutethimide, nadolol, phenobarbital, phenylbutazone, theophylline, and others (Campbell and Chyka, 1992).

Administrating multiple doses of activated charcoal work to decrease the absorption and blood concentration of many drugs. Giving multiple doses of activated charcoal implies giving an initial dose of 50-100g followed by supporting doses of of 30-50 g every 2-6 hours. Supporting doses of activated charcoal in the gut adsorbs the toxin once it is secreted back in to the gut, and by thus, a delayed peak in the serum concentration is inhibited (Jones and Volans, 1999).

The use of activated charcoal for treating patients with chronic kidney disease (ckd)

It has been suggested to use sorbents as alternative or supplementary treatment for patients with chronic kidney disease (ckd) (Ash, 2009). Other studies have pointed to the effects of these sorbents in eliminating waste products including urea, indoxyl sulfate (is) and other urinary toxins; and by thus enhance the dialysis process (Winchester and Ronco, 2010; Yamamoto et al., 2011; Schulman, 2012). Activated charcoal is considered one of these strong sorbents (Cooney, 1995; Olson, 2010; Vaziri et al., 2013).

Various forms of activated charcoals are given with low protein diets to control some uremic symptoms among patients with various stages of renal disease, and this is thought to occur via the binding of urea and other urinary toxins to charcoal, beside its excretion with feces, making a concentration gradient for continued diffusion of these toxins (Ash, 2009). It has also been reported to eliminate urinary toxins by charcoals (Fujii et al., 2009). There has been a report on beneficial effect in elderly patients with end-stage renal disease (esrd) (Musso et al., 2010). In another study, it has been reported that the use of activated charcoal (ac) and other alternative agents that have the ability to block the actions of profibrotic cytokines including transforming growth factor-beta (tgf-b), can either halt or prevent the development of ckd in early stages (Schulman, 2012).

Activated charcoal cartridges

Activated charcoal is used to offer protection from various organic vapors at workplace. Charcoal cartridges were designed for this purpose. Both of organic vapors and aerosol particles exist in the workplace atmosphere. Although it is possible to use gas respirators with activated charcoal cartridges, but it should be noted that the service life of the charcoal cartridges could be shortened due to aerosol loading in a work environment, from the perspective of respiratory protection (Kuo et al., 2013).

In their study, Innes et al., (1989) gave a description for activated charcoal in which it has a porous structure with variable gaps of molecular dimensions, and called the micropores. The micropores of charcoal have a slit-shape which its size ranges between 0.4 to 2 nm and represent the majority of the adsorption capacity. There are mesopores, with size varying from 2 to 50 nm, which are important for transport properties. The macropores also exist and identify those pores whose size exceed 50 nm (Kuo et al., 2013).

From a physical point of view, micropores have higher surface area to pore volume ratios than mesopores and macropores. The adsorption process depends on micropores and availability of contact surfaces in the adsorbents, and it is considered as a process of volume filling. Adsorption shifts gradually to what is called multilayer adsorption in the meso- and macropores with increasing the vapor pressure. The behavior of adsorption in mesopores depends on both vapor-wall interactions and the attractive forces between vapor molecules leading to a process called capillary (pore) condensation (Stoeckli, 1990).

Two main barriers to gas molecule diffusion have identified, pore entry and diffusion along the pore. Furthermore, the rate-limiting step in highly microporous carbons was found to be pore entry (Rao, 1985). Several studies on the factors affecting adsorption capacity and/or breakthrough time of a charcoal cartridge have been carried out (Nelson and Correia, 1976; Yoon and Nelson, 1990, 1992; Yoon et al., 1996). It has been indicated that the breakthrough properties of charcoal cartridges to be affected by the constituent(s) and the concentration(s) of the vapor(s) adsorbed (Nelson and Harder, 1974; Nelson and Correia, 1976; Tanaka et al., 1999; Dharmarajan et al., 2001), temperature (Nelson et al., 1976; James et al., 1984; Wood, 1985), moisture content in the gas flow in terms of relative humidity (Nelson et al., 1976; Yoon & Nelson, 1990; Tsai, 1994; Wood, 2004; Kaplan, 2006; Li, 2008; Ye, 2008; Cao, 2010; Bradley, 2011), gas flow rate (Nelson & Correia, 1976), and charcoal packing density (Trout, Breysse et al., 1986).

The use of activated charcoal for heavy metals removal

Pollution with heavy metals is considered a very serious problem threatening the environment. According to this context, it is a very important issue how to remove heavy metals from environment. The activated carbon was tested for its ability to remove lead, cadmium, nickel, chromium and zinc from water. Nickel had the highest removal percentages by activated carbon at all concentrations and the removal percentages decreased as the concentration of heavy metal increased (Karnib et al., 2014).

Due to the fact that heavy metals exist as natural components of the earth's crust, and heavy metals are associated with toxicity, exposure to heavy metals has been considered as a risk for human beings (Demirbas, 2008). It is worth to mention that the presence of zinc, cadmium, nickel and other metals in water has been associated with pathological conditions if the acceptable levels are exceeded (Hua et al., 2012). In their study, chingombe, saha, and Wakeman (2005) described several technologies including adsorption, precipitation, membrane filtration, and ion-exchange to be used to remove metal pollutants from water. Among these technologies, adsorption has proven to be economical and efficient for removing heavy metals, organic pollutants and dyes from polluted waters (Tangjuank et al., 2009).

References:

Aisha Ibrahim Maklad, Ashraf Mahmoud Emara and Enas Ibrahim El-Maddah, Mennat-Allah Ahmed Mahmoud El-Refai (2012). pediatric poisoning in Egypt. Journal of Applied Pharmaceutical Science, 2 (2): 1-6.

Ash, S.R (2009). Sorbents in treatment of uremia: a short history and a great future. Semin. Dial. 22, 615–622.

Bradley, R. H (2011). Surface studies of novel hydrophobic active carbons. Applied Surface Science, 257, 2912–2919.

Buckley N, Dawson A, Howarth D, Whyte I (1993). Slow release verapamil poisoning. Med J, 158:202-4.

Campbell J, Chyka P (1992). Physiochemical characteristics of drugs and response to repeat doses of activated charcoal. Am J Emerg Med, 10:208-10.

Cao, L (2010). Effect of relative humidity on adsorption capacity of organic vapors on activated carbon and prediction by the modified D-Requations. 2010 International Conference on Digital Manufacturing and Automation(ICDMA).

Chingombe P, Saha B, Wakeman R (2005). Surface modification and characterization of a coal-based activated carbon. Carbon, 43:3132–3143.

Cooney, D.O (1995). Activated Charcoal in Medical Applications. Marcel Dekker, NewYork.

Dasari Harish, K H Chavali, Amandeep Singh, Ajay Kumar (2011). Recent Advances in the Management of Poisoning Cases. J Indian Acad Forensic Med, 33, 1: 73-79.
Demirbas A (2008). Heavy metal adsorption onto agro-based waste materials: A review. Journal of Hazardous Materials, 157: 220–229.
Dharmarajan, V., Lingg, R.D., Myer, H.E. (2001). Evaluation of organic vapor respirator cartridge efficiency for hexamethylene diisocyanate vapor in the presence of organic solvents. Applied Occupational and Environmental Hygiene, 16, 397–404.
Fujii, H., Nishijima, F., Goto, S., Sugano, M., Yamato, H., Kitazawa, R., Kitazawa, S., Fukagawa, M (2009). Oral charcoal adsorbent (AST-120) prevents progression of cardiac damage in chronic kidney disease through suppression of oxidative stress. Nephrol. Dial. Transplant. 24, 2089–2095.
Hua M, Zhang S, Pan B, Zhang W, Lv L, Zhang Q. Heavy metal removal from water/wastewater by nanosized metal oxides: A review. Journal of Hazardous Materials 2012; 211:317– 331.
Jones AL, Volans G (1999). Management of self poisoning: recent advances. BMJ, 319: 1414-7.
Kaplan, D (2006). Effects of high relative humidity on the dynamic adsorption of dimethylmethyl phosphonate (DMMP)on activated carbon. Carbon, 44, 3247–3254.
Li, J (2008). Effect of relative humidity on adsorption of formaldehyde on modified activated carbons. Chinese Journal of Chemical Engineering, 16, 871–875.
Mona Karnib, Ahmad Kabbani, Hanafy Holail, Zakia Olama (2014). Heavy metals removal using activated carbon, silica and silica activated carbon composite. Energy Procedia 50, 113 – 120.
Musso, C.G., Michelangelo, H., Reynaldi, J., Martinez, B., Vidal, F., Quevedo, M., Parot, M., Waisman, G., Algranati, L (2010). Combination of oral activated charcoal plus low protein diet as a new alternative for handling in the old end-stage renal disease patients. Saudi J. Kidney Dis. Transpl. 21, 102–104
Nelson, G.O, Harder,C.A (1974). Respirator cartridge efficiency studies. V. Effect of solvent vapor. American Industrial Hygienist Association Journal, 35, 391–410.
Nelson, G.O., Correia,A.N (1976). Respirator cartridge efficiency studies: VIII. Summary and conclusions. American Industrial Hygienist Association Journal, 37, 514–525.
Neuvonen PJ, Olkkola, KT (1988). Oral activated charcoal in the treatment of intoxications [review]. Med Toxicol, 3:33-58.
Olson, K.R (2010). Activated charcoal for acute poisoning: one toxicologist's journey. J. Med. Toxicol. 6, 190–198.

Rao, M.B (1985). Mathematical modeling of diffusive potentials within carbon molecular sieves. Extended Abstracts and Program—Biennial Conference on Carbon,114–115.

Rowden AM, Spoor JE, Bertino JS (1990).The effect of activated charcoal on Phenytoin pharmacokinetics. Ann Emerg Med, 19: 1144-7.

Schulman, G (2012). A nexus of progression of chronic kidney disease: tryptophan, profibrotic cytokines, and charcoal. J. Ren. Nutr. 22, 107–113.

Stoeckli, H.F (1990). Microporous carbons and their characterization: the present state of the art. Carbon, 28, 1–6.

Tanaka, S., Nakano, Y., Tsunemori,K., Shimada, M., Seki, Y (1999). A study on the relative breakthrough time(RBT) of a respirator cartridge for forty-six kinds of organic solvent vapors. Applied Occupational and Environmental Hygiene, 14, 691–695.

Tangjuank S, Insuk N, Tontrakoon J, Udeye V (2009). Adsorption of lead (II) and Cadmium (II) ions from aqueous solutions by adsorption on activated carbon prepared from cashew nut shells. World Academy of Science, Engineering and Technology, 28:110-116.

Trout, D., Breysse, P. N., Hall, T., Corn, M., Risby, T (1986). Determination of organic vapor respirator cartridge evariability in terms of degree of activation of the carbon and cartridge packing density. American Industrial Hygienist Association Journal, 47, 491–496.

Tsai, W. T (1994). Surface chemistry of activated carbons and its relevance for effects of relative humidity on adsorption of chlorinated organic vapors. Chemosphere, 29, 2507-2507.

Winchester, J.F., Ronco, C (2010). Sorbent augmented hemodialysis systems: are we there yet? J. Am. Soc. Nephrol. 21, 209–211.

Wood, G. O. (2004). Estimating service lives of organic vapor cartridges II: A single vapor at all humidities. Journal of Occupational and Environmental Hygiene, 472–492.

Yamamoto, S., Zuo, Y., Ma, J., Yancey, P.G., Hunley, T.E., Motojima, M., Fogo, A.B., Linton, M.F., Fazio, S., Ichikawa, I., Kon, V., 2011. Oral activated charcoal adsorbent (AST-120) ameliorates extent and instability of atheroscleros is accelerated by kidney disease in apolipoprotein E-deficient mice. Nephrol. Dial. Transplant. 26, 2491–2497.

Ye, P (2008) .Study of adsorption kinetics of perfluoroisobutene on fixed bed activated carbon. Journal of Chemical and Engineering Data, 53, 1262–1265.

Yoon, Y.H., Nelson, J.H (1990). Effects of humidity and contaminant concentration on respirator cartridge breakthrough. American Industrial Hygienist Association Journal, 51, 202–209.

Yoon, Y.H., Nelson, J.H (1992). Breakthrough time and adsorption capacity of 3 respirator cartridges. American Industrial Hygienist Association Journal, 53, 303–316.

Yu-Mei Kuo, Chih-WeiLin, Sheng-HsiuHuang, Kuang-NanChang, Chih-Chieh Chen (2013). Effect of aerosol loading on breakthrough characteristics of activated charcoal cartridges. Journal of AerosolScience55, 57–65.

Innes, R.W.,Fryer,J.R., Stoeckli,H.F (1989). On the correlation between micropore distribution obtained from molecular probes and from high resolution electron microscopy. Carbon, 27, 71–76.

James, R., Dukes-Dobos, F., Smith, R (1984). Effects of respirators underheat/work conditions. American Industrial Hygienist Association Journal, 45, 399–404.

Wood, G.O (1985). Effects of air temperatures and humidities on efficiencies and life times of air-purifying chemical respirator cartridges tested against methyl iodide. American Industrial Hygienist Association Journal, 46, 251–256.

Yoon, Y. H. , Nelson, J.H., Lara, J (1996). Respirator cartridge service-life: exposure to mixtures. American Industrial Hygienist Association Journal, 57, 809–819.